

# Devicetree BOF

ELCE 2018  
Edinburgh, UK

Frank Rowand, Sony

October 24, 2018

181021\_1535

# My Goal

Do NOT show all of the slides

# Agenda

- Collect questions, areas of interest
- Past events
- Future events
- New since elc 2017
- dtc compiler update
- Overlay update
- questions, comments, issues, concerns from the crowd

# What do you want to talk about?

questions

comments

issues

concerns

# Plumbers 2017 Summary

September 2017

Los Angeles

Was not scheduled

-- not enough interest / commitment

# Devicetree Workshop Oct 2017

Prague, Czech Republic

after elce



# Devicetree Workshop Oct 2017

Prague, Czech Republic

[https://elinux.org/Device\\_tree\\_future  
#Kernel\\_Summit\\_2017.2C\\_Devicetree\\_Workshop](https://elinux.org/Device_tree_future#Kernel_Summit_2017.2C_Devicetree_Workshop)

- slides
- notes

Main topic areas:

- === Validation Tools & Schema
- === Runtime usage
- === DTS maintenance issues
- === More stuff

# Devicetree Workshop 2017

- 9:30 Welcome and Schedule bashing
- 9:40 Encoding and Schema checking: Framing the problem
- 9:45 DT YAML encoding overview
- 10:00 YAML encoding discussion
- 10:20 DT Schema format - option 1
- 10:35 DT Schema format - option 2
- 10:50 DT Schema discussion - what should go in the spec?
- 11:50 Code Generation from DT
- 12:10 Runtime memory consumption
- 14:30 Overlay maintenance plan
- 14:45 Avoiding duplicate descriptions
- 15:00 Criteria for accepting board files
- 15:15 Location for maintaining bindings - how to handle foreign bindings
- 15:30 Sharing Generic bindings
- 15:45 ABI Stability
- 16:00 [break and overflow discussion]
- 16:30 DT health check
- 16:50 devicetree.org update
- 17:05 EBBR Discussion
- 17:20 Closing and feedback



# Plumbers 2018

November 13 - 15, 2018

Tuesday - Thursday

Vancouver, British Columbia, Canada

co-located with the Linux Kernel Summit

Plumbers session:

Wednesday 14 November, morning

# Devicetree Specification

(old news...)

Devicetree Specification 0.1 **supersedes ePAPR for the Linux kernel, continues to evolve**

<https://www.devicetree.org/specifications/>

Mail list, Build Instructions, etc

<https://www.devicetree.org/collaborate/>

Repository

<https://github.com/devicetree-org/devicetree-specification>

# dtc Compiler

# dtc Compiler

commits from February 10, 2017 to date in dtc repo

- YAML encoded output format
  - \* for validation tools
- new library: pylibfdt
- ability to make nodes conditional on them being referenced
  - \* size reduction
- overlay syntactic sugar
  - \* eliminate hard coding overlay metadata
- fdtoverlay
  - \* standalone tool to apply overlay(s)

# dtc - Devicetree Build Checks

Rob has been enhancing dtc error checks

Enabled for “W=1” builds

```
$ make V=0 W=1 qcom-apq8074-dragonboard.dtb
```

```
make[1]: Entering directory `/local/frowand_nobackup/src/git_linus/build/dragon_linus_4.10'
```

```
  DTC      arch/arm/boot/dts/qcom-apq8074-dragonboard.dtb
```

```
Warning (unit_address_vs_reg): Node /memory has a reg or ranges property, but no unit name
```

```
Warning (unit_address_vs_reg): Node /soc/spmi@fc4cf000/pm8941@0/vadc@3100/die_temp
```

```
Warning (unit_address_vs_reg): Node /soc/spmi@fc4cf000/pm8941@0/vadc@3100/ref_625m
```

```
Warning (unit_address_vs_reg): Node /soc/spmi@fc4cf000/pm8941@0/vadc@3100/ref_1250v
```

```
Warning (unit_address_vs_reg): Node /soc/spmi@fc4cf000/pm8941@0/vadc@3100/ref_gnd h
```

```
Warning (unit_address_vs_reg): Node /soc/spmi@fc4cf000/pm8941@0/vadc@3100/ref_vdd h
```

```
make[1]: Leaving directory `/local/frowand_nobackup/src/git_linus/build/dragon_linus_4.10'
```

# dtc - Devicetree Build Checks

commits from February 10, 2017 to date in dtc repo

- add SPI bus checks
- add I2C bus checks
- drop warning for missing PCI bridge bus-range
- add graph binding checks
- add a check for duplicate unit-addresses of child nodes
- add chosen node checks
- add aliases node checks
- check for #{size,address}-cells without child nodes
- add string list check for \*-names properties
- add string list check
- add a string check for 'label' property
- add interrupts property check
- add gpio binding properties check
- add phandle with arg property checks
- Warn on node name unit-addresses with '0x' or leading 0s
- Add bus checks for simple-bus buses
- Add bus checks for PCI buses
- Add Warning for stricter node name character checking
- Add Warning for stricter property name character checking

# Overlay

# Overlay

- U-Boot overlay support
  - enhancements have been added

Alternative to Linux kernel overlay loader  
for some use cases



# overlay validation - Linux kernel

Patches under review on mail list, not yet accepted to main line - may change

[PATCH v4 00/18] of: overlay: validation checks, subsequent fixes  
Mon, 15 Oct 2018 19:37:20 -0700

<https://lore.kernel.org/lkml/>

1539657458-24401-1-git-send-email-frowand.list@gmail.com/T/#u

Overlay loader remains out of tree, so validation will only be visible for unittest, FPGAs, or if you use the out of tree overlay loader

Exposed errors in core devicetree code  
Fixes are in the patch series

# validation - ERROR, WARNING

WARNING: memory leak will occur if overlay removed, property: <prop\_path>

cause: property add or modify in node not created by an overlay

ERROR: memory leak before free overlay changeset, <node\_path>

cause: too many of\_node\_put()

ERROR: memory leak, expected refcount 1 instead of <refcount>, of\_node\_get()/of\_node\_put() unbalanced - destroy cset entry: attach overlay node <node\_path>

cause: too many of\_node\_get() or not enough of\_node\_put()

# validation - ERROR

Malformed FDT will not cleanly apply

ERROR: changing value of #address-cells is not allowed in <node\_path>

ERROR: changing value of #size-cells is not allowed in <node\_path>

ERROR: multiple fragments add and/or delete node <node\_path>

ERROR: multiple fragments add, update, and/or delete property <prop\_path>

## ERROR: multiple fragments add and/or delete node <node\_path>

```
# drivers/of/unittest-data/overlay_bad_add_dup_node.dts:
```

```
// SPDX-License-Identifier: GPL-2.0
```

```
/dts-v1/;
```

```
/plugin/;
```

```
/*
```

```
 * &electric_1/motor-1 and &spin_ctrl_1 are the same node:
```

```
 *   /testcase-data-2/substation@100/motor-1
```

```
 *
```

```
 * Thus the new node "controller" in each fragment will
```

```
 * result in an attempt to add the same node twice.
```

```
 * This will result in an error and the overlay apply
```

```
 * will fail.
```

```
 */
```

```
&electric_1 {
```

```
    motor-1 {
```

```
        controller {
```

```
            power_bus = < 0x1 0x2 >;
```

```
        };
```

```
    };
```

```
};
```

```
&spin_ctrl_1 {
```

```
    controller {
```

```
        power_bus_emergency = < 0x101 0x102 >;
```

```
    };
```

```
};
```

ERROR: multiple fragments add, update, and/or delete property <prop\_path>

# drivers/of/unittest-data/overlay\_bad\_add\_dup\_prop.dts:

```
// SPDX-License-Identifier: GPL-2.0
/dts-v1/;
/plugin/;
```

```
/*
 * &electric_1/motor-1 and &spin_ctrl_1 are the same node:
 *   /testcase-data-2/substation@100/motor-1
 *
 * Thus the property "rpm_avail" in each fragment will
 * result in an attempt to update the same property twice.
 * This will result in an error and the overlay apply
 * will fail.
 */
```

```
&electric_1 {
    motor-1 {
        rpm_avail = < 100 >;
    };
};

&spin_ctrl_1 {
    rpm_avail = < 100 200 >;
};
```

# Linux Internal ERROR

ERROR: of\_node\_release(), unexpected properties in <node\_path>

# Metadata

How should the metadata required by overlays be encoded in the FDT?

Discussion was in progress on devicetree-compiler list

Subject: [RFC] devicetree: new FDT format version

Message-ID: <b96829f9-2e8b-fdc5-5090-58591e2260cf@gmail.com>

Date: Mon, 22 Jan 2018 00:09:18 -0800

side-effect: update of FDT format required

# Metadata

## Motivation:

- size reduction of FDT and kernel data
- remove metadata from tree name space

## side-effects:

- update of FDT format required
- additional features possible, eg
  - \* phandle as property value decompile
  - \* validation features



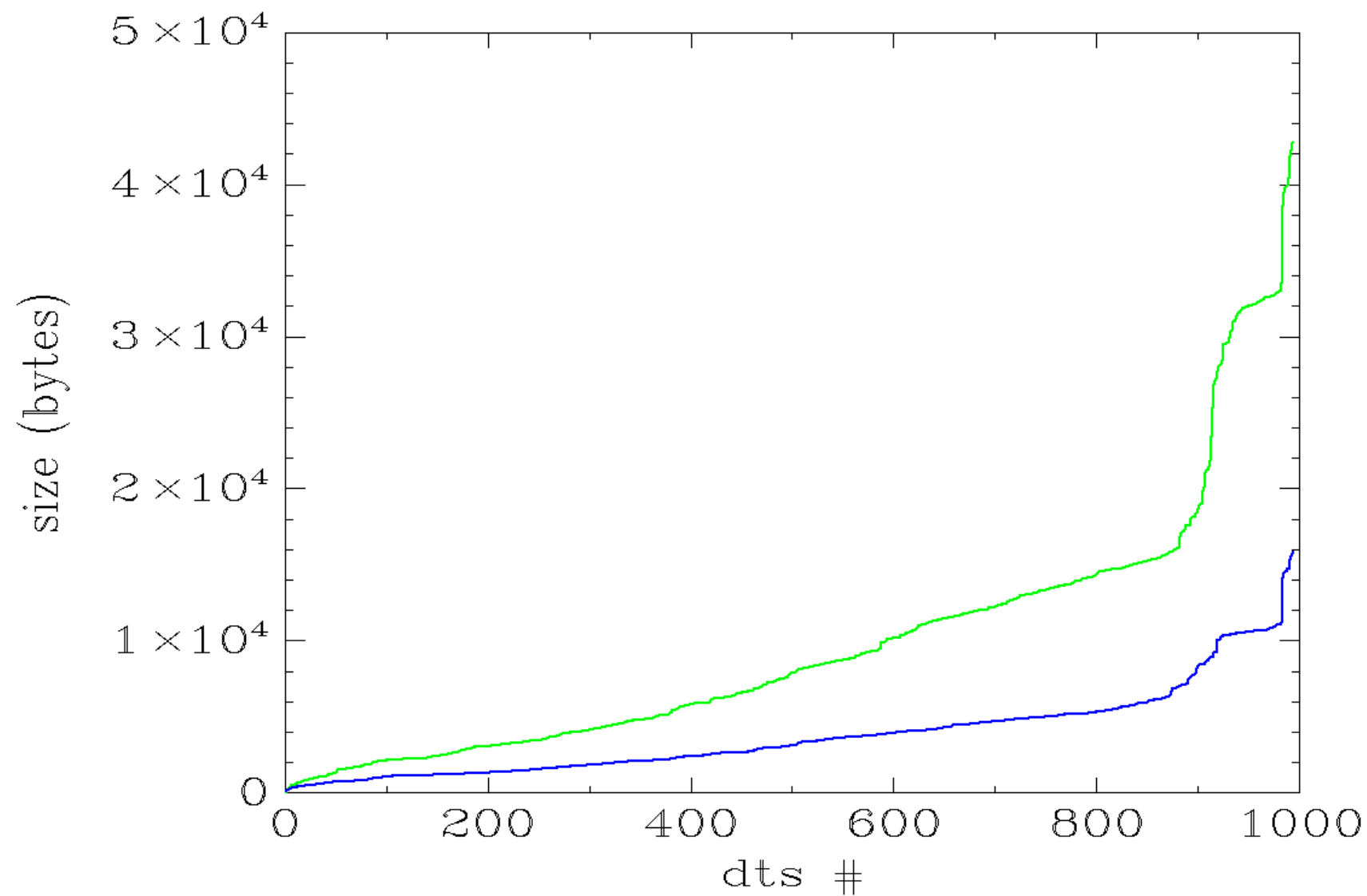
# Metadata - base FDT overhead

Metadata overhead measured for arch/arm/boot/dts/\*

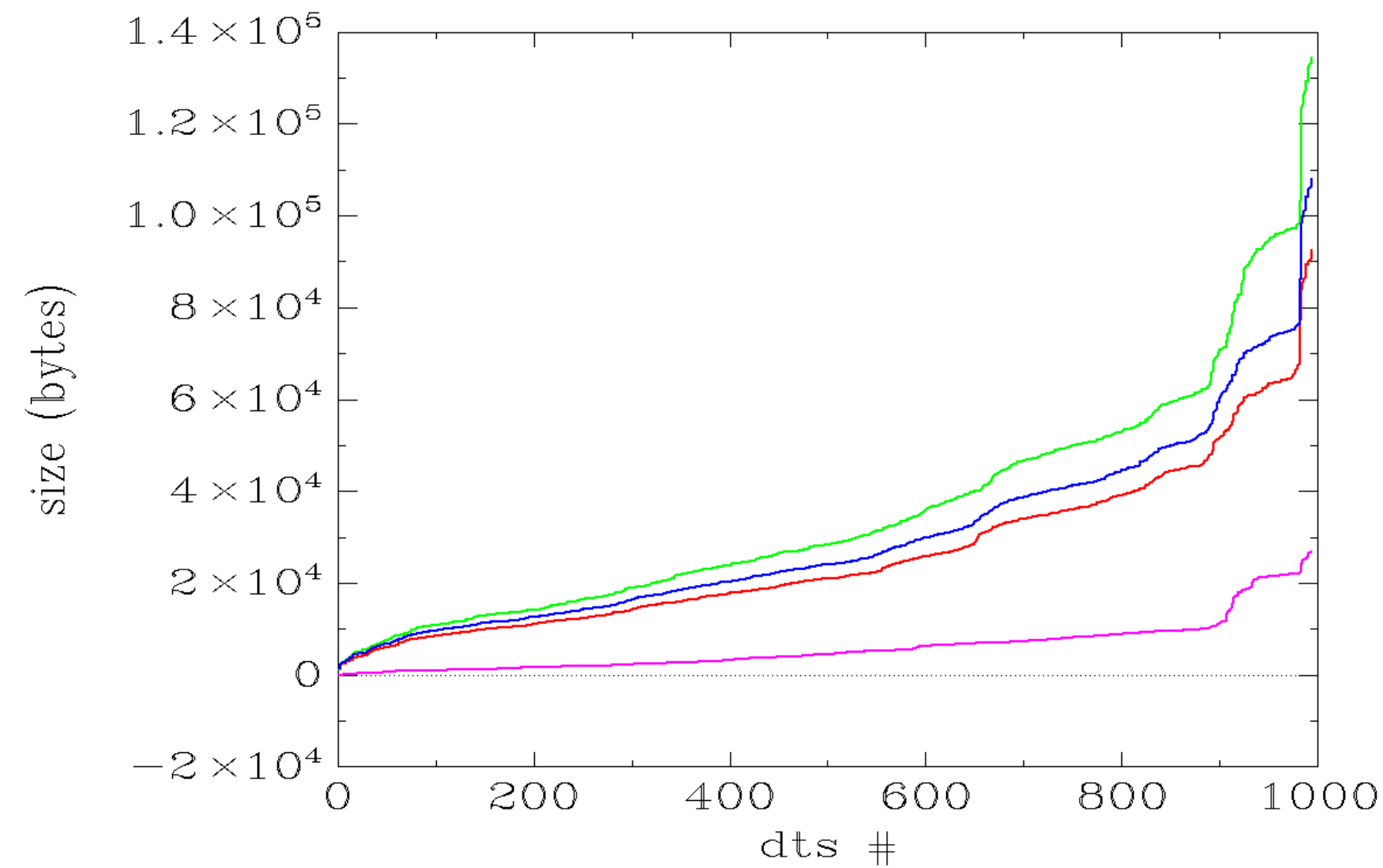
“**symbols old fmt**” is added size from '**dtc -@**'  
for the **current FDT format**

“**symbols new fmt**” is added size from '**dtc -@**'  
for **first proposed format in the email thread**

FDT size, sort on: new format symbols  
symbols old fmt, symbols new fmt



FDT size, sort on: saved  
old fmt, new fmt, no symbols, saved



# Metadata - base FDT overhead

Metadata overhead measured for arch/arm/boot/dts/\*

row	dtb no symbols	delta symbols	delta new fmt	bytes saved
----	-----	-----	-----	-----
99%	90531	42721	15766	26955
83%	44302	14582	5163	9419
66%	26277	11662	4628	7034
49%	21047	7328	2754	4574
33%	12864	4305	1705	2600
16%	12009	2929	1520	1409
0%	1220	68	149	-81

- “**delta symbols**” is added size from '**dtc -@**'
- “**new fmt**” is added size from '**dtc -@**' for first proposed in the email thread

# dtc - overlays - Linux v4.15

dtc creates the .dtb **OVERLAY INTERNAL DATA**  
(“metadata”)

**Do not hand code overlay internal data nodes  
in DTS source:**

```
fragment@  
__overlay__  
__fixup__  
__local_fixup__  
__symbols__
```

# dtc - overlays - example - old.dts

```
/dts-v1/;
/plugin/;

/ {
    fragment@0 {
        target-path = "/soc/base_fpga_region";
        #address-cells = <1>;
        #size-cells = <1>;

        __overlay__ {
            ranges = <0x00000000 0x00000000 0xc0000000 0x00040000>,
                    <0x00000001 0x00000000 0xff200000 0x00001000>;

            external-fpga-config;

            #address-cells = <2>;
            #size-cells = <1>;

            fpga_pr_region0 {
                compatible = "fpga-region";
                fpga-bridges = <&freeze_controller_0>;
                ranges;
            };

            freeze_controller_0: freeze_controller@100000450 {
                compatible = "altr,freeze-bridge-controller";
                reg = <0x00000001 0x00000450 0x00000010>;
                interrupt-parent = <&intc>;
                interrupts = <0 21 4>;
            };
        };
    };
};
```

# dts - overlays - example - new.dts

```
/dts-v1/;  
/plugin/;
```

```
&fpga_region {  
    ranges = <0x00000000 0x00000000 0xc0000000 0x00040000>,  
            <0x00000001 0x00000000 0xff200000 0x00001000>;  
  
    external-fpga-config;  
  
    #address-cells = <2>;  
    #size-cells = <1>;  
  
    fpga_pr_region0 {  
        compatible = "fpga-region";  
        fpga-bridges = <&freeze_controller_0>;  
        ranges;  
    };  
  
    freeze_controller_0: freeze_controller@100000450 {  
        compatible = "altr,freeze-bridge-controller";  
        reg = <0x00000001 0x00000450 0x00000010>;  
        interrupt-parent = <&intc>;  
        interrupts = <0 21 4>;  
    };  
};
```

# dtc - overlays - example

```
$ diff -b -u old.dts new.dts
--- old.dts
+++ new.dts
@@ -1,13 +1,7 @@
 /dts-v1/;
 /plugin/;

-/ {
-     fragment@0 {
-         target-path = "/soc/base_fpga_region";
-         #address-cells = <1>;
-         #size-cells = <1>;
-         __overlay__ {
+&fpga_region {
             ranges = <0x00000000 0x00000000 0xc0000000 0x00040000>,
                    <0x00000001 0x00000000 0xff200000 0x00001000>;

@@ -28,6 +22,4 @@
             interrupt-parent = <&intc>;
             interrupts = <0 21 4>;
         };
     };
};
```



# dtc - overlays - new.dts - no label?

```
/dts-v1/;  
/plugin/;  
  
&fpga_region {  
    .....  
};
```

What if there is no label for the overlay target in the base devicetree?

What if the overlay target is the root node (dtc does not allow a label on the root node)?

# dtc - overlays - example - new.dts

```
/dts-v1/;
/plugin/;

&{/soc/base_fpga_region} {
    ranges = <0x00000000 0x00000000 0xc0000000 0x00040000>,
             <0x00000001 0x00000000 0xff200000 0x00001000>;

    external-fpga-config;

    #address-cells = <2>;
    #size-cells = <1>;

    fpga_pr_region0 {
        compatible = "fpga-region";
        fpga-bridges = <&freeze_controller_0>;
        ranges;
    };

    freeze_controller_0: freeze_controller@100000450 {
        compatible = "altr,freeze-bridge-controller";
        reg = <0x00000001 0x00000450 0x00000010>;
        interrupt-parent = <&intc>;
        interrupts = <0 21 4>;
    };
};
```

# next expected format change

Explicit connector node

# .dtsi source vs overlay .dtsi

(More slides available after the 'END' slide)

# Overlays

[https://elinux.org/Frank%27s\\_Evolving\\_Overlay\\_Thoughts](https://elinux.org/Frank%27s_Evolving_Overlay_Thoughts)

# What do you want to talk about?

questions

comments

issues

concerns

# How to get a copy of the slides

- 1) [frank.rowand@sony.com](mailto:frank.rowand@sony.com)
- 2) [http://elinux.org/Device\\_Tree](http://elinux.org/Device_Tree)
- 3) <http://events.linuxfoundation.org>

THE END

Thank you for your participation...



# .dtsi source vs overlay .dtsi

With the new dtc --

Overlay .dts file contains directives:

```
/dts-v1/;
```

```
/plugin/;
```

.dtsi include file does not

# Use include as .dtsi or overlay

With sugar syntax, the syntax used by an overlay is now compatible with the syntax used by an include file, if the include file uses labels as paths instead of using explicit paths.

- This may be convenient for development workflows
- Do not become dependent on this for overlays that will be long lived -- current thinking is that we want many / most overlays to use the connector model

# Use include as .dtsi or overlay

## ----- base tree -----

```
$ expand fpga_tree.dts
/dts-v1/;

/* labels used by overlay are in the base tree */

/ {
    soc {
        intc: interrupt_ctrl {
        };
        fpga_region: base_fpga_region {
        };
    };
};

/include/ "fpga_plugin_or_dtsi.dts"
```

## ----- overlay -----

```
$ expand fpga_overlay.dts
/dts-v1/;
/plugin/;

/include/ "fpga_plugin_or_dtsi.dts"
```

# The .dtsi

```
$ expand fpga_plugin_or_dtsi.dts
&fpga_region {
    ranges = <0x00000000 0x00000000 0xc0000000 0x00040000>,
            <0x00000001 0x00000000 0xff200000 0x00001000>;

    external-fpga-config;

    #address-cells = <2>;
    #size-cells = <1>;

    fpga_pr_region0 {
        compatible = "fpga-region";
        fpga-bridges = <&freeze_controller_0>;
        ranges;
    };

    freeze_controller_0: freeze_controller@100000450 {
        compatible = "altr,freeze-bridge-controller";
        reg = <0x00000001 0x00000450 0x00000010>;
        interrupt-parent = <&intc>;
        interrupts = <0 21 4>;
    };
};
```

# Tools

# Kernel Configuration Info -- OLD

## In tree

```
scripts/dtc/dt_to_config \
arch/arm/boot/dts/qcom-apq8074-dragonboard.dts \
--short-name \
--config ${KBUILD_OUTPUT}/.config \
--config-format \
> dragon_config_info
```

```
$ grep -i coincell dragon_config_info
```

```
# -d-c-----n--F : coincell@2800 : qcom,pm8941-coincell : drivers/misc/qcom-coincell.c : CONFIG_QCOM_COINCELL : n
# CONFIG_QCOM_COINCELL is not set
# CONFIG_QCOM_COINCELL=y
```

```
# -d-c-----n--F : coincell@2800 : qcom,pm8941-coincell : .....
# CONFIG_QCOM_COINCELL is not set
# CONFIG_QCOM_COINCELL=y
```

# Debug Tools - OLD - update

dtc: dts source location annotation

- Provide source locations from .dts & .dtsi
- Several proof of concept versions on devicetree-compiler list, up to October 2015
- ~~Stalled, awaiting some of Frank's bandwidth~~

Project picked up by Julia Lawall

To: devicetree-compiler@vger.kernel.org

Subject: [PATCH 1/3 v4] annotations: check for NULL position

Date: Fri, 2 Feb 2018 21:41:48 +0100

# source location annotation (old)

----- short format -----

```
sdhci@f9824900 { /* qcom-apq8074-dragonboard.dts:14 */
    compatible = "qcom,sdhci-msm-v4"; /* qcom-msm8974.dtsi:240 */
    reg = <0xf9824900 0x11c 0xf9824000 0x800>; /* qcom-msm8974.dtsi:241 */
    reg-names = "hc_mem", "core_mem"; /* qcom-msm8974.dtsi:242 */
    interrupts = <0x0 0x7b 0x0 0x0 0x8a 0x0>; /* qcom-msm8974.dtsi:243 */
    interrupt-names = "hc_irq", "pwr_irq"; /* qcom-msm8974.dtsi:244 */
    clocks = <0xd 0xd8 0xd 0xd7>; /* qcom-msm8974.dtsi:245 */
    clock-names = "core", "iface"; /* qcom-msm8974.dtsi:246 */
    status = "ok"; /* qcom-apq8074-dragonboard.dts:17 */
    bus-width = <0x8>; /* qcom-apq8074-dragonboard.dts:15 */
    non-removable; /* qcom-apq8074-dragonboard.dts:16 */
}; /* qcom-apq8074-dragonboard.dts:18 */
```



# Debug Tools -- semi-OLD

scripts/dtc/dt\_prop

- Compare properties accessed on target system vs a device tree (dtX)
- available on [elinux.org](http://elinux.org)
- ~~Plan to submit to mail list “any day now”~~  
==> Stalled, awaiting some of Frank's bandwidth

# dt\_prop example snippets

```
$ dt_prop --td dmesg_4.5-rc5_160307_2100 qcom-apq8074-dragonboard.dts
```

```
# --- dmesg_4.5-rc5_160307_2100
# +++ qcom-apq8074-dragonboard.dts
/dts-v1/;
```

```

// ***** i2c@f9964000 disabled *****
i2c@f9964000 {
+       #address-cells;
+       #size-cells;
+       clock-names;
+       clocks;
        compatible;
+       interrupts;
+       reg;
        status;
};
```

# Debug Tools - OLD

dt\_node\_info, dt\_stat

- Aids boot (or module load) debugging
- Status of device creation, devicetree nodes, driver discovery, driver binding
- proof of concept on [elinux.org](http://elinux.org)
- Stalled, awaiting some of Frank's bandwidth

# dt\_node\_info example 1

```
$ dt_node_info coincell
```

```
===== devices
```

```
===== nodes
```

```
/soc/spmi@fc4cf000/pm8941@0/qcom,coincell@2800 qcom,
```

```
===== nodes bound to a driver
```

```
===== nodes with a device
```

```
===== nodes not bound to a driver
```

```
/soc/spmi@fc4cf000/pm8941@0/qcom,coincell@2800 qcom,
```

```
===== nodes without a device
```

```
/soc/spmi@fc4cf000/pm8941@0/qcom,coincell@2800 qcom,
```

# dt\_node\_info example 2

```
$ dt_node_info coincell
```

```
===== devices
```

```
/sys/devices/platform/soc/fc4cf000.spmi/spmi-0/0-00/
```

```
===== nodes
```

```
/soc/spmi@fc4cf000/pm8941@0/qcom,coincell@2800 qcom,
```

```
===== nodes bound to a driver
```

```
===== nodes with a device
```

```
/soc/spmi@fc4cf000/pm8941@0/qcom,coincell@2800 qcom,
```

```
===== nodes not bound to a driver
```

```
/soc/spmi@fc4cf000/pm8941@0/qcom,coincell@2800 qcom,
```

```
===== nodes without a device
```

# Overlays -- more stuff...

# Overlays - some use cases

- Expansion slots / external connectors
  - beaglebone
  - raspberry pi
  - minnowboard
  - C.H.I.P.
  - Arduino
  - seeedstudios Grove 4 pin connectors
  - others?
- FPGA

# Overlays - some use cases

- Combinatorial explosion of .dts / .dtb files

example:

Devicetree Hardware Autoconfiguration

Hans de Goede

ELC Europe 2016



# Overlays, one of the gating factors

On 10/18/17 14:46, Frank Rowand wrote:

> On Wed, 2017-10-18 at 10:44 -0500, Rob Herring wrote:

>> The issue remains that the kernel is not really setup to deal with any  
>> random property or node to be changed at any point in run-time. I  
>> think there needs to be some restrictions around what the overlays can  
>> touch. We can't have it be wide open and then lock things down later  
>> and break users.

> That paragraph is key to any discussion of accepting code to apply overlays.  
> Solving that issue has been stated to be a gating factor for such code from  
> the beginning of overlay development.

(Not the only remaining issue.)

# Overlays, Linux kernel progress

(Not a complete list)

- overlay.c refactored
- resolver.c refactored
- hand coded overlays in devicetree source files
  - resolved by sugar syntax if base tree has required labels
  - continued dtc enhancements underway
- papered over issue: free FDT or expanded devicetree while pointers into them still exist
- unable to free overlay FDT and overlay expanded device tree after overlay removal (memory leak)
- FDT format update up in the air
- of locking architecturally broken
- pre-removal checks needs to ensure relevent driver(s) unbind
- connectors architecture up in the air
- overlay semantics not fully specified
- overlay manager (do not accept until gating requirements are resolved)

# Devicetree Development History

Some random statistics

# v4.2.. arch/\*/boot/dts/ commits

550	arc
54641	arm
13170	arm64
4	c6x
44	cris
93	h8300
33	metag
2	microblaze
1054	mips
31	nios2
7	openrisc
797	powerpc
25	sh
115	xtensa

# arch/\*/boot/dts/ commits

v4.2	638			
v4.3	592			
v4.4	666			
v4.5	725			
v4.6	682			
v4.7	722			
v4.8	674			
v4.9	719	2017	02	19
v4.10	768	2017	04	30
v4.11	632			
v4.12	658			
v4.13	687			
v4.14	725			
v4.15	762			

# arch/\*/boot/dts/ commits

	arm	arm64			
v4.2	568	36			
v4.3	535	46			
v4.4	553	67			
v4.5	571	137			
v4.6	511	149			
v4.7	559	117			
v4.8	498	156			
v4.9	489	195			
v4.10	519	235	2017	02	19
v4.11	456	151	2017	04	30
v4.12	434	217			
v4.13	381	283			
v4.14	401	294			
v4.15	503	219			

# .../bindings/ commits

v4.2	488			
v4.3	411			
v4.4	418			
v4.5	467			
v4.6	428			
v4.7	445			
v4.8	418			
v4.9	453			
v4.10	491	2017	02	19
v4.11	421	2017	04	30
v4.12	468			
v4.13	460			
v4.14	494			
v4.15	438			

# scripts/dtc/ commits

v4.2	2			
v4.3	0			
v4.4	0			
v4.5	0			
v4.6	3			
v4.7	1			
v4.8	1			
v4.9	0			
v4.10	0	2017	02	19
v4.11	1	2017	04	30
v4.12	6			
v4.13	6			
v4.14	2			
v4.15	4			



# drivers/of/ commits

v4.2 29

v4.3 16

v4.4 38

v4.5 22

v4.6 29

v4.7 40

v4.8 30

v4.9 24

**v4.10 28 2017 02 19**

**v4.11 19 2017 04 30**

v4.12 32

v4.13 36

v4.14 38

v4.15 52

# v4.10.. top drivers/of/ commits

(February 19, 2017 ..)

What have patch topics been?

Very imprecise topic count (do not take the list too seriously...)

Based mostly on leading fields of patch subject

# v4.10.. top drivers/of/ commits

(loosely based by patch comment tag)

```
23 overlay
10 device property
12 test
 7 of_mdio
 7 irq
 6 fdt
 6 of_graph
 6 device
 5 pci
 4 platform
 3 base
```

# Resources

[http://elinux.org/Device\\_Tree\\_presentations\\_papers\\_articles](http://elinux.org/Device_Tree_presentations_papers_articles)

[http://elinux.org/Device\\_Tree\\_presentations\\_papers\\_articles#debug](http://elinux.org/Device_Tree_presentations_papers_articles#debug)

[http://elinux.org/Device\\_Tree\\_Reference](http://elinux.org/Device_Tree_Reference)

# Resources

## Devicetree Documentation

[elinux.org/Device\\_Tree\\_Reference](http://elinux.org/Device_Tree_Reference)

- becoming more complete
- contributions and comments welcome

# Resources

**dtx\_diff**

**dtc --annotate**

**dt\_node\_info**

Solving Device Tree Issues:

Frank Rowand, elce 2015

[http://elinux.org/images/0/04/Dt\\_debugging\\_elce\\_2015\\_151006\\_0421.pdf](http://elinux.org/images/0/04/Dt_debugging_elce_2015_151006_0421.pdf)

(In this presentation, dtx\_diff was named dtdiff.)

Supporting material for: Solving Device Tree Issues:

[http://elinux.org/Device\\_Tree\\_frowand](http://elinux.org/Device_Tree_frowand)

section: Embedded Linux Conference Europe (ELCE) - October 6, 2015

**dt\_to\_config**

Solving Device Tree Issues - Part 2:

Frank Rowand, LinuxCon Japan 2016

[http://elinux.org/images/5/50/Dt\\_debugging\\_part\\_2.pdf](http://elinux.org/images/5/50/Dt_debugging_part_2.pdf)

# Resources

## dt\_prop

Solving Device Tree Issues - Part 3:

Frank Rowand, elce 2016

[http://elinux.org/images/e/e5/Dt\\_debugging\\_part\\_3.pdf](http://elinux.org/images/e/e5/Dt_debugging_part_3.pdf)

Supporting material for: Solving Device Tree Issues - Part 3:

kernel patches

scripts/dtc/dts\_diff

scripts/dtc/dt\_prop

[http://elinux.org/Device\\_Tree\\_frowand](http://elinux.org/Device_Tree_frowand)

section: Resources for "Solving Device Tree Issues - Part 3" talk